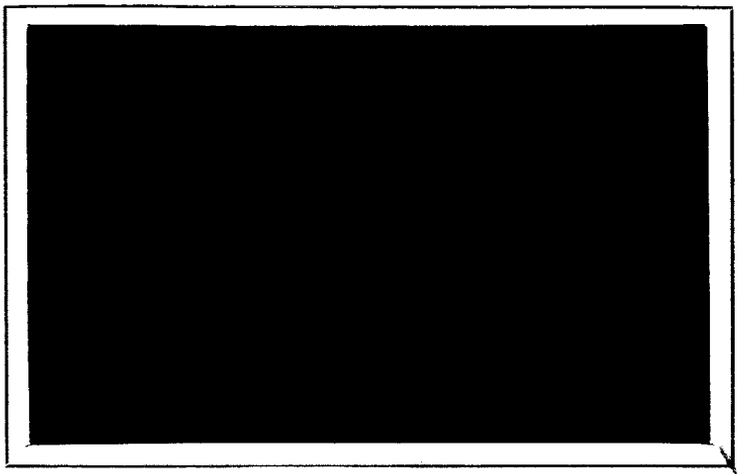

Dept. of Industrial Cooperation

UNIVERSITY OF MAINE

Orono, Maine

PROGRESS REPORT ON RESEARCH ACTIVITY

UNDER INSTITUTIONAL GRANT NsG-338

TO

NATIONAL AERONAUTICS & SPACE ADMINISTRATION

BY

T. H. CURRY

JULY 1 TO DECEMBER 31, 1965

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ON RESEARCH ACTIVITY

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UNIVERSITY OF MAINE

ORONO, MAINE

ABSTRACT

As a part of the agreement with NASA under institutional grant No. NsG-338, the University of Maine reports semi-annually to NASA on projects supported under the grant. This document summarizes research activity for the period July 1 to December 31, 1965.

INTRODUCTION

Several of the projects initiated in 1962 have terminated while others approved last spring are just getting under way. In general the research is proceeding satisfactorily and is resulting in student theses and journal publications.

The University of Maine Space Research Committee, which has responsibility for approving projects and awarding funds under our institutional grant, feels encouraged because of the increased interest in space related research and because of the general improvement in quality of proposals to the Committee.

COMPLETED PROJECTS

Below are listed projects which have terminated since the last semi-annual report. This resulted from achievement of the research objective or from transfer of the principal investigator to another educational institution or to industry.

Title	Investigator(s)	Department(s)
Application of Modern Communication Theory Techniques to the Analysis of Electrocardiographic Functions	Dr. E. M. Sheppard	Electrical Engineering

Project resulted in two M.S. theses and led to project with Animal Sciences Department.

Title	Investigator(s)	Department(s)
Effect of Increasing CO_2 Tension of Inspired Air on Nutrient Intake and Digestibility	Dr. W. H. Hoover Dr. B. R. Poulton	Animal Sciences

An M.S. thesis and a manuscript for publication are being prepared. This project resulted in further work involving Animal Sciences and Electrical Engineering with assistance from the Animal Pathology Department.

Interrelations of Type of Atmosphere, Carbon Dioxide Concentration and Chemical Stimulation of the Photosynthetic Response in Green Plants	Dr. G. R. Cooper	Botany and Plant Pathology

A new investigation on "artificial gravity" has resulted from this project.

Design and Study of a New Apparatus for the Determination of Second Virial Coefficients of Organic Vapors	Dr. R. D. Dunlap	Chemistry

Resulted in an M.S. thesis.

Discontinuous Rate Compensation for Servo Systems	Prof. W. W. Turner	Electrical Engineering

Led to two M.S. theses and a manuscript, included in the Appendix of this report, which has been submitted for publication.

A Force-Momentum Demonstration Apparatus	Dr. G. T. Davis Prof. R. C. Hill	Education and Mechanical Engineering

Research completed. Publication expected.

Study of Interface Phenomena in Filament Wound Glass Reinforced Plastic Composites	Prof. C. A. Bouc	Engineering Graphics

Prof. Bouc has moved to another institution.

Title	Investigator(s)	Department(s)
Solid State Amplifier for Measuring Cardiac Potentials	Prof. H. T. MacFarland	Electrical Engineering
A Tunnel-Diode Transmitter for the Measurement of Gastric Acidity	"	"

Prof. MacFarland has taken employment in industry.

ACTIVE PROJECTS

Below are listed the research projects now being conducted at Maine under NASA support.

An Investigation of the Effects of Radiation on BaF_2:Gd and SrF_2:Gd Using The Electron Spin-Resonance (ESR) Technique	Dr. D. W. Wylie	Physics
Response of Green Plants to Artificial Gravity as Simulated by Electrostatic Fields and Applied Potentials	Dr. G. R. Cooper	Botany and Plant Pathology
Variations in Biochemical Properties of a Photosynthetic Protist as a Function of Environmental Conditions in Chemostat Cultures	Dr. J. R. Cook	Zoology
Electron Temperature Measurement for a Radio Frequency Discharge in a Magnetic Field	Dr. G. S. Harmon	Physics
Function of Abnormally Fragile Tissue Membrane in Fatigue-Induced Stress	Dr. J. A. Smith	Biochemistry
A Study of Digestibility of Plant Tissue in Animals and the Effect of Stress on the Metabolism of Plant Tissue Culture	Dr. A. R. Whitehill Dr. F. H. Bird	Bacteriology
Effect of Metabolic Rate and Loading on Temperature Regulations and Survival in a Highly Conductive Atmosphere	Dr. C. W. Major	Zoology
University of Maine Space Lecture and Consultation Series	Dr. B. R. Poulton Chairman	General University

Title	Investigator(s)	Department(s)
A Bio-Engineering Study of Effects of CO_2 Stress on the Physiology and Nutrition of Animals	Dr. W. H. Hoover Dr. E. M. Sheppard Dr. B. R. Poulton Prof. C. M. Brown	Animal Sciences and Electrical Engineering
The Dimensionality and Cognitive Demands of Certain Science and Mathematic Problems and Their Relationships to Convergent and Divergent Thinking Tasks and Anxiety	Dr. F. W. Ohnmacht Dr. G. T. Davis Dr. John Lindlof	Education
Study of Attitudes Concerning Death	Dr. G. M. Vernon	Sociology
Classical Eyelid Conditioning in Rats: Bioelectric Correlates	Dr. H. C. Ebel	Psychology
Concerning Strictly Singular Operators	Prof. R. B. Mericle	Mathematics
Investigation of Parameters Fundamental to Optimization of Drag Turbines	Dr. W. L. Schneider Prof. J. G. Klavuhn	Mechanical Engineering
The Effect of Repeated Rolling Contact Stress Fields on the Microstructure of High Carbon Medium Hardness Steel	Prof. John Lyman	Mechanical Engineering

RESEARCH PROGRESS DURING PERIOD JULY 1 TO DECEMBER 31, 1965

Summaries of research conducted under each of the active projects are reported in the Appendix.

Respectfully submitted,

T. H. Curry
for the University Space Research Committee:

Dr. Ralph E. Armington
Dr. George F. Dow
Dr. Franklin P. Eggert
Prof. Richard C. Hill
Dr. Edward S. Northam
Dr. H. Austin Peck
Dr. Bruce R. Poulton
Dr. George A. Prescott
Dr. Frederick H. Radke
Dr. Arnold H. Raphaelson
Dr. Benjamin R. Speicher

APPENDIX

Research progress reports on the following projects for the period July 1 to December 31, 1965:

DISCONTINUOUS RATE COMPENSATION FOR SERVO SYSTEMS - Prof. W. W. Turner

AN INVESTIGATION OF THE EFFECTS OF RADIATION ON BaF_2:Gd and SrF_2:Gd USING THE ELECTRON SPIN-RESONANCE (ESR) TECHNIQUE - Dr. D. W. Wylie

RESPONSE OF GREEN PLANTS TO ARTIFICIAL GRAVITY AS SIMULATED BY ELECTROSTATIC FIELDS AND APPLIED POTENTIALS - Dr. G. R. Cooper

VARIATIONS IN BIOCHEMICAL PROPERTIES OF A PHOTOSYNTHETIC PROTIST AS A FUNCTION OF ENVIRONMENTAL CONDITIONS IN CHEMOSTAT CULTURES - Dr. J. R. Cook

ELECTRON TEMPERATURE MEASUREMENT FOR A RADIO FREQUENCY DISCHARGE IN A MAGNETIC FIELD - Dr. G. S. Harmon

THE FUNCTION OF ABNORMALLY FRAGILE TISSUE MEMBRANE IN FATIGUE-INDUCED STRESS - Dr. J. A. Smith

EFFECT OF METABOLIC RATE AND LOADING ON TEMPERATURE REGULATIONS AND SURVIVAL IN A HIGHLY CONDUCTIVE ATMOSPHERE - Dr. C. W. Major

UNIVERSITY OF MAINE SPACE LECTURE AND CONSULTATION SERIES - Dr. B. R. Poulton

A BIO-ENGINEERING STUDY OF EFFECTS OF CO_2 STRESS ON THE PHYSIOLOGY AND NUTRITION OF ANIMALS - Drs. W. H. Hoover, E. M. Sheppard, et al

THE DIMENSIONALITY AND COGNITIVE DEMANDS OF CERTAIN SCIENCE AND MATHEMATIC PROBLEMS AND THEIR RELATIONSHIPS TO CONVERGENT AND DIVERGENT THINKING TASKS AND ANXIETY - Dr. F. W. Ohnmacht et al

STUDY OF ATTITUDES CONCERNING DEATH - Dr. G. M. Vernon

CLASSICAL EYELID CONDITIONING IN RATS: BIOELECTRIC CORRELATES - Dr. H. C. Ebel

CONCERNING STRICTLY SINGULAR OPERATORS - Prof. R. B. Mericle

INVESTIGATION OF PARAMETERS FUNDAMENTAL TO OPTIMIZATION OF DRAG TURBINES - Dr. W. L. Schneider and Prof. J. G. Klavuhn

THE EFFECT OF REPEATED ROLLING CONTACT STRESS FIELDS ON THE MICROSTRUCTURE OF HIGH CARBON MEDIUM HARDNESS STEEL - Prof. John Lyman

Note: Copies marked "MASTER" contain one-of-a-kind photographs, graphs or brochures.

DISCONTINUOUS RATE COMPENSATION OF SERVO SYSTEMS

Professor Walter W. Turner
Department of Electrical Engineering

Introduction

A large volume of work has been accomplished in the recent past on optimalizing a control system in the sense of minimum time to accomplish some prescribed task. Results show that if the control variables are bounded in magnitude, minimum response time is realized if the system is operated "bang-bang" so that maximum corrective action is taken at all times.[1] Successful operation under these conditions requires that switching from maximum positive to maximum negative corrective action must occur at exactly the right point and that the system be shut off or corrective action removed at the exact instant when the system state variables are all zero. Both of these conditions are difficult to realize in practice and if they are not satisfied, limit cycle or other undesirable operation may result.[2]

Consider a system with tachometric feedback which is driven by a step function. Assume that the sense of the tachometric feedback is initially such that the system is quite underdamped but is reversed at an appropriate time so that the system is overdamped. It would appear that such a system might exhibit a small overshoot and a short settling time without requiring the exact switching of the bang-bang control. The system just described will be referred to as a discontinuous rate compensated (DRC) system.

This paper develops a justification for the reasoning outlined above and reports the results of simulation studies in which the response of a

system with discontinuous rate compensation is compared with the response of the same system with bang-bang control.

Development of Mathematical Model

The system under consideration is shown in Figure 1. All parts of the system are assumed to be linear except for block n which is restricted so that $|n| \leq 1$. If r is restricted to be a step function, the response of the system will be the same as obtained by letting r=0 and setting the initial value of c equal to the magnitude of the step input. With r=0, the system is equivalent to Figure 2. Thus the characteristic equation for the system is

$$\ddot{c} + (\beta + nK_2K_3)\dot{c} + K_1K_2c = 0 \tag{1}$$

Introducing state variables, $x_1=c$ and $x_2=dc/dt$, the state equations are

$$\begin{aligned} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= K_1K_2x_1 - (\beta + nK_2K_3)x_2 \end{aligned} \tag{2}$$

Using the terminology of Athans,[1] the cost function L is equal to unity for minimum times response and the Hamiltonian is given by

$$H = L + \langle \dot{\underline{x}}, \underline{p} \rangle \tag{3}$$

where $\langle \dot{\underline{x}}, \underline{p} \rangle$ represents the dot product of

$$\dot{\underline{x}} = \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} \text{ by } \underline{p} = \begin{bmatrix} p_1 \\ p_2 \end{bmatrix}$$

and $\underline{p}$ is defined by $\partial H/\partial x_i = -\dot{p}_i$, $i = 1,2$ (4)

Expanding (3)

$$\begin{aligned} H &= 1 + \dot{x}_1p_1 + \dot{x}_2p_2 = 1 + p_1x_2 + p_2\left[-K_1K_2x_1 - (\beta + nK_2K_3)x_2\right] \\ &= 1 + p_1x_2 - p_2K_1K_2x_1 - p_2\beta x_2 - p_2nK_2K_3x_2 \end{aligned} \tag{5}$$

H will be an absolute minimum subject to $|n| \leq 1$ when

$n = \text{sgn}^* p_2K_2K_3x_2 = \text{sgn } p_2x_2$ (if K_2 and K_3 are both positive). This indicates that n should be plus one or minus one depending on the sign of p_2x_2. It now remains to determine when n should be plus one and when it should be minus one.

Using (4) and (5)

$$\dot{p}_1 = -\partial H/\partial x_1 = p_2K_1K_2$$

$$\dot{p}_2 = -\partial H/\partial x_2 = -p_1 + p_2\beta + p_2nK_2K_3$$

Solving these simultaneously yields

$$\ddot{p}_1 - (\beta + nK_2K_3)\dot{p}_1 + K_1K_2p_1 = 0 \qquad (6)$$

Comparison of (6) with (1) shows that the state variables $\underline{x}$ differ from the costate variables $\underline{p}$ only in the sign of the damping term. Thus if x_2 is a decaying sinusoid p_2 will be an exponentially increasing sinusoid with the same magnitude of time constant. A similar result obtains if x_2 is characterized by an overdamped response.

The sign of n depends on p_2x_2 and, if the equation of this product is known, the control function is determined. Initial values of x_2 are determined by the physical problem but initial values of p_2 are not necessarily obtainable. Following Athans[3] approach, an attempt would be made to determine the maximum number of switchings that can occur. It can be shown that if the system is overdamped, the sign of p_2x_2 can change no more than twice. However, the change of n from +1 to -1 may well result in an underdamped response in which case p_2x_2 may change sign a large number of times before equilibrium is reached. (A limit cycle may be the

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* $\text{sgn } y = \dfrac{y}{|y|}$

equilibrium condition if both values of n yield an underdamped system. It is also possible that for n = -1 the system will be unstable.) It is now necessary to select from all possible $n(p_2,x_2)$ which satisfy the conditions for minimum H the particular n which results in minimum time.

Determination of Optimum Switching Points

Consideration of the physical problem reveals that the time to equilibrium will be theoretically infinite regardless of the final value of n. For this reason it is more realistic to specify a range of controlled variable $\pm\epsilon$ such that the system transient may be considered completed at a time beyond which the controlled variable does not exceed $\pm\epsilon$. In this paper ϵ will be assumed to be 5 percent of the step drive magnitude.

The necessary reasoning is best demonstrated by a numerical example. In Figure 1 let $K_1 = 1.62$, $\beta = 3$, $K_2 = 10$, $K_3 = 0.4$. If the plant to be controlled is represented by the block containing K_2, and β, equation (1) with n = 0 shows that the response without tachometric feedback would be characterized by a damping ratio of 0.37 and a natural frequency of 4.0 radians per second. The response of such a system to a step input would exhibit a 28 percent overshoot and a settling time (to 5%) of approximately 2.3 seconds.

Figure 3a shows the system trajectories for a variety of initial conditions when n = +1 and Figure 3b shows the trajectories when n = -1. Minimum response time for a given initial condition is realized when the area between the system trajectory and the x_1 axis is maximum. Figure 3c shows the two sets of trajectories superposed. Examination of Figure 3c indicates that minimum time to 5 percent is realized if n is initially -1 and is switched to +1 at the intersection with the trajectory tangent to the negative side of the $\pm$ 5 percent region.

Table 1

Comparison of Settling Time (to 5%)

Initial Value of C	Bang-Bang System	DRC System W/o Sat.	DRC System With Sat.
0.5	0.31	0.50	0.49
1.0	0.45	0.50	0.50
1.5	0.57	0.50	0.53
2.0	0.67	0.50	0.57
2.5	0.77	0.50	0.60
3.0	0.86	0.50	0.63
3.5	0.95	0.50	0.66
4.0	1.04	0.50	0.69

Table 2

Comparison of Maximum Velocities

Initial Value of C	Bang-Bang System	DRC System W/o Sat.	DRC System With Sat.
0.5	2.68	1.8	1.8
1.0	3.51	3.6	3.6
1.5	4.15	5.4	5.2
2.0	4.40	7.0	6.5
2.5	4.70	8.8	7.6
3.0	4.88	10.6	8.7
3.5	5.00	12.3	9.8
4.0	5.12	14.0	10.9

Table 3

Comparison of Maximum Accelerations

Initial Value of C	Bang-Bang System	DRC System W/o Sat.	DRC System With Sat.
0.5	23.5	8.3	8.4
1.0	26.0	17.0	16.3
1.5	27.8	25.8	22.5
2.0	28.5	33.3	29.0
2.5	29.5	42.5	36.0
3.0	30.0	51.0	44.0
3.5	30.5	58.5	52.0
4.0	31.0	66.5	58.0

Simulation Study

In order to determine the relative effectiveness of this type controller the system was simulated[4] on an analog computer and results obtained for a variety of initial values of x_1, with x_2 (0) = 0. A conventional "bang-bang" system having the configuration of Figure 4 was also simulated and studied for the same initial conditions. It was assumed here that amplifier K, saturated at an output level of 1.62.

In the analytical development it was assumed that the entire system is linear except for the function n in the tachometric loop. This was done to make the mathematics more tractable. It seems reasonable, however, that saturation of the K_1 amplifier should be included if a meaningful comparison is to be made between the response of the "bang-bang" system and that of the discontinous rate system. Saturation at the same level as in bang-bang operation was simulated on the computer and results obtained experimentally for the same switching sequence as used for the discontinuous rate system without saturation. Some results of the computer studies are shown in Tables 1 through 3. Initial velocity in all cases is zero. All time is in seconds, velocities are in radians per second and accelerations are in radians per second per second.

In comparing the performance data it should be kept in mind that the switching point in the phase plane for the DRC system is not particularly critical. For instance if switching occurs too early, the only effect will be a slightly longer response time but with lower overshoot. If switching occurs too late, the response will exhibit more than five percent overshoot and the time to five percent will be correspondingly longer. In either case however the possibility of limit cycle operation is not present.

In some applications the five percent criterion for settling time may not be acceptable. Examination of Figure 3c shows that smaller overshoot can be realized simply by switching at the intersection with the n = +1 trajectory corresponding to the desired overshoot. The area under the complete trajectory will be slightly smaller corresponding to a small increase in settling time.

With these points in mind, examination of Tables 1 through 3 indicates that the DRC system of control exhibits (at least for the numerical values used) some advantages over bang-bang control, with regard to settling time. The reduction in settling time is realized at the expense of higher maximum velocities and accelerations.

Conclusions

For one type of system and one type of drive it has been demonstrated that the system with discontinuous rate compensation responds more rapidly than with "time-optimal" bang-bang control. To realize this improvement the system must withstand higher velocities and accelerations.

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1. M. Athanassiades, "Optimal Control for Linear Time Invariant Plants with Time, Fuel, and Energy Constraints," AIEE Transactions, pt. II (Applications and Industry), vol. 81, 1962 (Jan. 1963 section), pp. 321-25.

2. J. J. O'Donnell, "Bounds of Limit Cycles in Two-Dimensional Bang-Bang Control Systems with an Almost Time-Optimal Switching Curve," IEEE Transactions on Automatic Control, vol. AC-9, October 1964, pp. 448-57.

3. M. Athans, "Minimum-Fuel Feedback Control System: Second-Order Case", IEEE Transactions on Applications and Industry, vol. 82, Mar. 1963, pp. 8-17.

4. R. J. Levesque, "Time-Optimal Response of Feedback Control Systems by means of Discontinuous Rate Compensation", unpublished Master's thesis, University of Maine, January 1966.

AN INVESTIGATION OF THE EFFECTS OF RADIATION ON BaF_2:Gd and SrF_2:Gd USING THE ELECTRON SPIN RESONANCE (ESR) TECHNIQUE - Dr. D. W. Wylie

Problem

The purpose of this investigation is to determine the effects of radiation on single crystals of BaF_2:Gd. Since these crystals have laser properties, a study of the crystalline electric field is of interest and in particular the effects of ionizing radiation on crystals is of interest if these materials are developed to the point of being used in the space program.

It is also of interest to further investigate the various charge compensation mechanisms which result from the substitution of Ga^{+++} for Ba^{++}. A third area of interest is the possibility of producing atomic displacements with ionizing radiation. This has been detected in other crystals so it would be of interest to see if the radiation only changes the ionization state or if, indeed, atomic displacements do take place.

Results

Since the last report the nature of the discrepancy between the spectra from different crystals has been resolved. The third or pre-cut crystal seems to have a large Fe^{+++} impurity content. This produces a five line spectrum which has been isolated. The computer program originally written for the Gd^{+++} ions has been modified and the angular variation of the Fe^{+++} spectrum has been theoretically computed. The agreement with the experiment is reasonably good. Another facet of the discrepancy was resolved when it was discovered that one of the faces was not a (100) as prescribed by the company.

Further analysis of the effects of radiation on the crystals is continuing.

THE RESPONSE OF GREEN PLANTS TO ARTIFICIAL GRAVATY AS SIMULATED BY ELECTROSTATIC FIELDS AND APPLIED POTENTIALS - Dr. G. R. Cooper

Problem

The problem of weightlessness has been shown to be a serious one in space. This project would attempt to establish an artificial polarity of transport and development within the plant which would produce normal plant responses under weightless conditions. Electrical fields, magnetic fields and electrical potentials will be applied singly or in combination to suitable plants and perhaps later to animals.

Results

As a result of a favorable literature review and some exploratory work, a project proposal was drawn up for direct submission to NASA, for comment. This review was favorable and a more fully detailed project was prepared and submitted to NASA as a formal proposal.

Work is still being carried on with support from the University's institutional grant. A summary of the procedures and results follow:

1. Coleus cuttings from a common parent are made and rooted to assure a common clove or genetic pattern for all test plants.
2. At a height of approximately 20 cm. they are brought into the laboratory for testing.
3. The plants are always used in pairs, one to be subjected to treatment, the other to be used as a control specimen.
4. The platinum wire electrodes used are shaped to fit lightly around the stems of both the control and experimental plants.
5. An electrical potential is applied for varying periods and also of a given magnitude.

6. The test and control plants are placed in various attitudes with respect to the horizontal and vertical axes of the plant.

7. Photographs are taken at intervals to record the response of the plants.

8. In one preliminary test the plants were killed, embedded and microscope slides prepared to determine the anatomical effects of the applied potential. This study will be continued.

9. Effects of low voltage DC on stem growth.

   a. Potato plants

      1) Runs at 25 voltage DC between the stem spex and its base resulted in the formation of black bands in the internodal regions.

      2) One run at 25 voltage DC resulted in a stem growing horizontally instead of vertically.

   b. Tomato plants

      1) Runs at 25 voltage DC with the stem apex positive gave identical results to those on potato.

   c. Coleus plants

      1) Runs at 25 voltage DC gave black bands in the internodal area as on potato and tomato.

      2) Micro-sections of the stems showed a plasmolysis and shrinkage of the parenchyma cells in the black band regions.

      3) Runs at 5 voltage DC were satisfactory in that plants which were grown in a horizontal position did not exhibit the normal geotropic and/or phototropic response although the control plant reacted normally to both light and gravity.

d. Coleus plants and their normal electrical potentials

1) A Corning model 12 pH meter has been adapted to use as an electrometer for measuring the normal values of electrical potential in the plant.

2) Two types of electrodes have been employed, plain platinum wire electrodes and a pair of calomel electrodes. It is planned to go to Ag-AgCl electrodes in the near future.

3) Electrical potentials of several Coleus plants are listed in the following table.

Average electrical potential of several Coleus plants between stem apex base in the vertical position or top and bottom sides of stem in a horizontal position. 1965.

Vertical Top to Base in millivolts	Horizontal Upper side and to lower, in millivolts
69.5	30

4) In each case the upper region of the plant was positive in relation to the lower portion.

10. Relationship of project to Space Technology.

a. The literature indicates that weightlessness presents real problems to living organisms, especially long-term weightlessness.

b. The mechanisms of geotropic responses of plants have never been completely or satisfactorily elucidated.

c. This project is aimed directly at both of the above -- its purpose is to counteract the adverse effects of weightlessness by the substitution of a reasonable counteracting bio-electric force.

COPY

January 14, 1966

Dear Dean Curry:

In response to your request for further data on my NASA project, I might add the following:

1. Runs at 5 volts DC while satisfactory under 12 hours of light and 12 hours of dark were very quickly fatal to the apical portion of Coleus plants under continuous dark conditions.

2. Runs at 5 volts DC were satisfactory under continuous light conditions.

3. Runs at 1 volt DC are now in progress but definite data is not yet available.

4. The continuous dark at 5 volts DC raises interesting questions on the whole subject of translocation within the plant.

5. It would appear that we have developed a new tool for the experimental determination of some of the heretofore nebulous aspects of translocation within green plants.

Yours truly,

(signed)

George R. Cooper

VARIATIONS IN BIOCHEMICAL PROPERTIES OF A PHOTOSYNTHETIC PROTIST AS A FUNCTION OF ENVIRONMENTAL CONDITIONS IN CHEMOSTAT CULTURES - Dr. J. R. Cook

Results of this research has been submitted for publication as follows:

1. Studies on chloroplast replication in synchronized Euglena. Chapter accepted for publication in the book "Cell Synchrony: Studies in Biosynthetic Regulation," ed. I. W. Cameron and A. M. Padilla, Academic Press, Inc. Probable date of publication June 1966.
2. Photo-inhibition of cytokinesis associated with chloroplast morphogenesis in Euglena. Submitted to Nature for possible publication.

When reprints are available, copies will be sent to NASA.

ELECTRON TEMPERATURE MEASUREMENTS FOR A RADIO FREQUENCY DISCHARGE IN A MAGNETIC FIELD - Dr. G. S. Harmon

Objective

The purpose of this work has been to obtain meaningful values for the electron temperature of a radio frequency gas discharge in a steady, uniform magnetic field.

There were two reasons for attempting this study: 1) there is some question as to the validity of probe data used to determine electron temperatures when used in the presence of a magnetic field, and 2) such data as exists does indicate a rise in temperature with increasing magnetic field for a rf discharge, in contrast to a drop, for a dc discharge.

Report on Research Progress

We have made simultaneous temperature measurements using probes and a microwave radiometer for a discharge in air. The results are shown in the accompanying figure. The rise in temperature with magnetic field is confirmed. The two curves do not agree above approximately 700 gauss. It is proposed that the mean free path of electrons, here made to decrease as the magnetic field increases, drops below the sheath thickness surrounding the probes. Under this condition the distribution of electron velocities striking the probe is no longer Maxwellian, thus leaving the analysis of probe data invalid.

Work is being continued to study the effect of varying the electron density, the gas pressure, and the exciting radio frequency. Also, absolute (rather than relative) temperature measurements will be made with the radiometer.

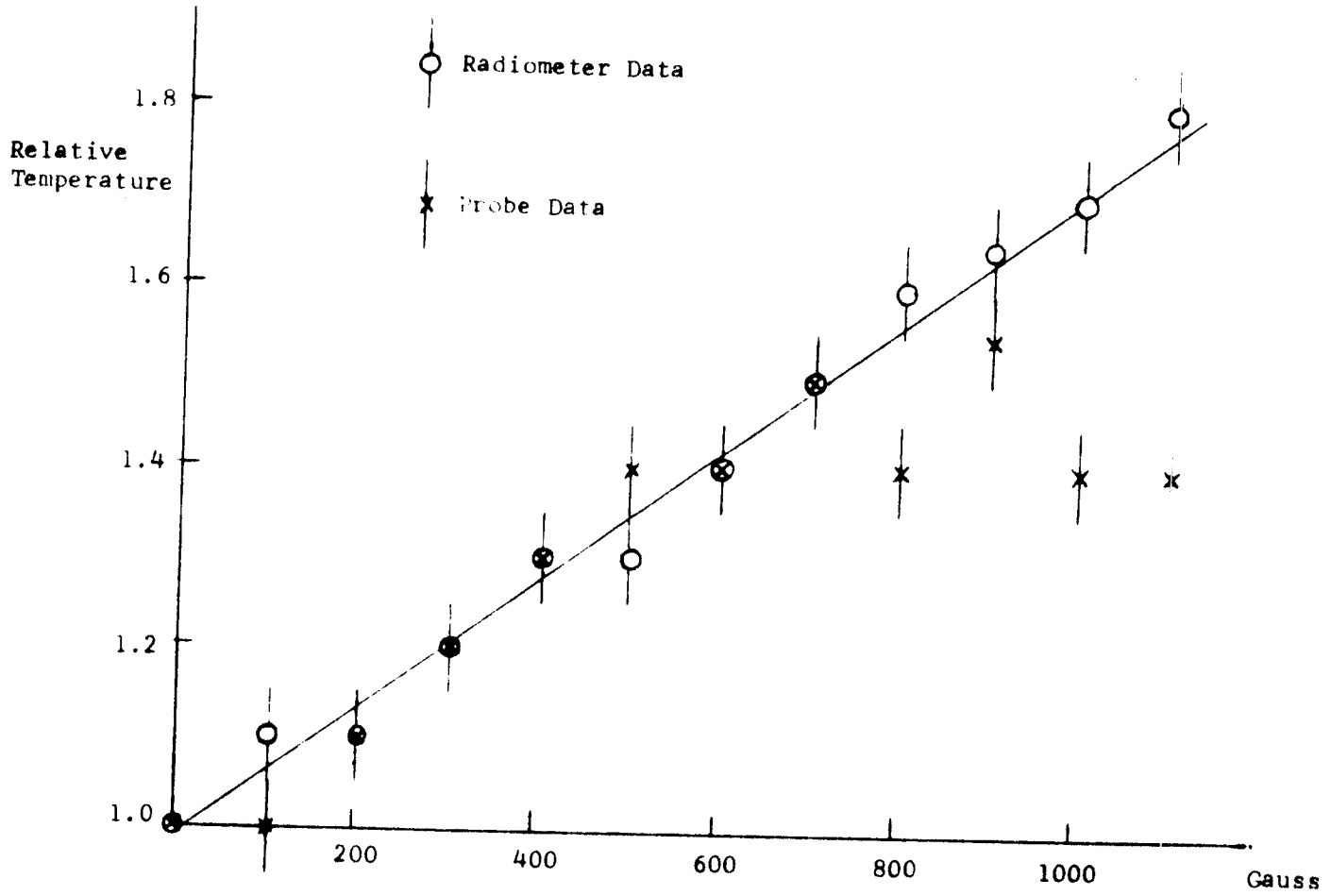

Fig. 3. Relative Electron Temperature As a Function of Longitudinal Magnetic Field.

THE FUNCTION OF ABNORMALLY FRAGILE TISSUE MEMBRANES IN FATIGUE-INDUCED STRESS - Dr. J. A. Smith

Introduction

The objective of this research project is to study the effect of physical stress on the function of tissue membranes made abnormally fragile as a result of a dietary deficiency of certain polyunsaturated fatty acids known as the essential fatty acids (EFA). Previous work on this project has suggested that subjecting adequately nourished rats to physical stress for 48 hours increased their metabolic rate as measured by carbon dioxide production to a level similar to that observed with EFA deficient rats regardless of the condition of stress. This observation raised the question of whether cell-free liver preparations would reflect this effect of stress *in vitro* and, if so, could this be the result of faulty membrane structure.

It is well known that liver motochondria from EFA deficient rats exhibit an increased adenosine triphosphatase (ATPase) activity, a loss of respiratory control, and, under certain conditions, a dissociation of oxidation from phosphorylation(1). Furthermore, these aberrations have been shown to be accompanied by an abnormal structural fragility of the mitochondria. It has been suggested that the biochemical defects observed in mitochondria isolated from EFA deficient rats are the result of some non-specific aberration such as altered membrane structure rather than with a lack of EFA at a specific site in the electron transport chain(2). It then follows that the increased metabolic rate exhibited by stressed, adequately nourished rats *in vivo* could be, in part at least, the result of weakened mitochondrial membrane structures.

The data presented here would suggest that mitochondria isolated from adequately nourished rats which have undergone 48 hours of physical stress

exhibit several of the biochemical defects which are observed in mitochondria from EFA deficient rats but that the severity of the lesions is not as great as is observed in EFA deficiency. In contrast physical stress accentuates the biochemical lesions observed in mitochondria isolated from EFA deficient rats.

Methods

The dietary treatment of the rats and the mode of application of stress has been described previously (see progress report Oct. 11, 1965). At the termination of stress the rats were injected intraperitoneally with 20 uc carrier-free acetate-1-C^{14} and placed in a Roth metabolism cage. Carbon dioxide was collected in 1 M NaOH at intervals over a three hour period.

The rats were then killed and the liver removed and placed in cold isotonic sucrose solution. One half of each liver was frozen for subsequent lipid analysis; and the other half was used to make a 10% homogenate in 0.20 M sucrose containing 0.05 M tris buffer pH 7.4. The oxidative capacity of the liver homogenates was determined by standard manometric techniques at 37°C.

Liver mitochondria were isolated from 10% homogenates in 0.20 M sucrose - 0.05 M tris buffer pH 7.4, by differential centrifugation at 2-4°C according to the method of Schneider (3). An aliquot of the isolated mitochondria were resuspended in the sucrose solution for the determination of the oxidative capacity, phosphate esterification activity, and ATPase activity. The remainder of the mitochondria were frozen for subsequent lipid analysis.

The media used in the manometric analyses contained 40 μmoles phosphate buffer pH 7.4, 20 μmoles magnesium chloride, 4 μmoles ATP, 0.08 μmoles cyto-

chrome c (horseheart, Sigma Co.), 0.5 ml of the mitochondrial suspension equivalent to approximately 1 mg N, substrate, and 0.20 M sucrose-0.05M tris buffer, pH 7.4. Where a phosphate acceptor was required, 1 mg hexokinase and 9 mg glucose were added per flask at the expense of an equivalent volume of the sucrose-tris solution. The substrates embyed and the concentrations of each were as follows: citrate and succinate, 45 μmoles; α-ketoglutarate and glutamate, 30 μmoles; and fumarate and pyruvate, 15 μmoles. Total volume of the incubation mixture was 3 ml with 0.2 ml 10% KOH in the center well.

The degree of phosphate esterification was determined by measuring the initial and residual inorganic phosphate in the incubation medium after the reaction was terminated by the addition of 1 ml 20% perchloric acid. Inorganic phosphate was determined by the method of Gomori (4). These incubations were carried out for at least 15 minutes at 30°C.

The incubation mixture for the determination of mitochondrial ATPase activity contained 6 μmoles ATP, 5 μmoles magnesium chloride, 20 μmoles tris buffer, pH 7.2, 0.2 ml of the mitochondrial suspension and sucrose-tris mixture to give a total volume of 1 ml. The non-enzymatic hydrolysis of ATP was determined routinely by substituting an equivalent volume of sucrose-tris mixture for the mitochondrial suspension. The inorganic phosphate of the mitochondrial suspension was found to be insignificant and, therefore, this determination was not run routinely. The inorganic phosphate released after ten minutes incubation time was determined by the method of Gomori (4).

Mitochondrial nitrogen was determined for each mitochondrial suspension according to the method of Johnson (5).

Results

Liver homogenates from EFA deficient rats oxidized α-ketoglutarate and succinate at a markedly higher rate than did liver homogenates from rats receiving a dietary source of EFA (Table I). The rate of oxidation of fumarate and glutamate was also slightly increased but the oxidation of pyruvate showed no difference. The imposition of 24 hours of physical stress on EFA deficient rats resulted in a marked increase in the oxidative capacity of liver homogenates with all substrates tested. This effect of stress was also observed in liver homogenates from adequately nourished rats which had been stressed for 48 hours. However, there was effect due to stress, particularly with the oxidation of pyruvate and succinate.

Similar experiments using isolated liver mitochondria gave analagous results if a phosphate acceptor was not incorporated into the incubation medium (Table II). However, the increase in oxidative rate due to stress was not as pronounced as that observed with liver homogenates. Addition of hexokinase-glucose as a phosphate acceptor system to the medium increased the rate of mitochondrial oxidation of all substrates. In this case the highest oxidative rate was obtained with mitochondria isolated from unstressed, adequately nourished rats. Liver mitochondria isolated from EFA deficient rats showed a marked loss of oxidative capacity which was not accentuated by physical stress except when succinate was used as a substrate. A less severe loss of oxidative capacity was shown by liver mitochondria from adequately nourished rats which had been stressed for 48 hours.

The decrease in oxidative capacity of the liver mitochondria from EFA deficient, stressed and unstressed rats was accompanied by a loss of respiratory control and an increase in mitochondrial ATPase activity

(Table III). These effects of physical stress were also noted in the metabolic activity of liver mitochondria from stressed, adequately nourished rats but again the effects were much less severe than those observed in mitochondria from EFA deficient animals.

EFA deficient mitochondria also showed an impaired capacity to esterfy phosphate in association with oxidation (Table IV). Stress appeared to accentuate the degree of uncoupling of oxidation from phosphorylation by mitochondria from EFA deficient rats but had little or no effect on the phosphorylating capacity of liver mitochondria from stressed, adequately nourished rats.

Table I

Oxidative Activity of Liver Homogenates from Stressed Rats[1]

Dietary Treatment	Fat-Free	5% Corn Oil	Fat-Free	5% Corn Oil
Length of stress in hours	0	0	24	48
Substrate		μl O_2/hr/mg N		
Pyruvate[2]	119[3]	115	155	120
α-Ketoglutarate	133	93	189	131
Fumarate	109	85	146	102
Succinate	173	130	228	137
Glutamate	124	93	194	124

1. Experimental conditions as described in the text.

2. o.6 μmoles fumarate added.

3. Each value represents at least 6 determinations.

Table II

Influence of EFA Deficiency and Physical Stress on the Respiratory Activity of Liver Mitochondria[1]

Dietary Treatment	Fat-Free	5% Corn Oil	Fat-Free	5% Corn Oil
Length of Stress in hours	0	0	24	48
Substrate		$\mu L\ O_2/hr/mg\ N$		
Citrate	140[2]	172	140	138
Succinate	442	549	312	417
α-Ketoglutarate	163	286	179	211
Glutamate	205	372	232	269
α-Ketoglutarate[3]	105	60	114	65
Glutamate[3]	106	59	115	66

1. Experimental conditions were as described in the text.
2. Each value represents at least 5 determination.
3. No phosphate acceptor system was added.

Table III

Effect of Stress on Mitochondrial ATPase Activity and Respiratory Control[1]

Dietary Treatment	Hours of Stress	μmoles ATP split 10 min./mg N	Respiratory Control[2] α-Ketoglutarate	Glutamate
Fat-Free	0	2.74	1.62	2.12
5% Corn Oil	0	0.89	4.94	6.21
Fat-Free	24	4.14	1.41	1.92
5% Corn Oil	48	1.72	4.31	5.23

1. Experimental conditions were as described in the text. Each value represents at least five determinations.

2. Respiratory control is defined as the ratio of the rate of oxidation in the presence of a phosphate acceptor to the rate of oxidation in the absence of a phosphate acceptor.

Table IV

Ratio of Phosphate Esterified to Oxygen Uptake by Isolated Liver Mitochondria[1]

Dietary Treatment	Fat-Free	5% Corn Oil	Fat-Free	5% Corn Oil
Length of Stress in hours	0	0	24	48
Substrate				
Citrate	1.19[2]	2.56	0.88	2.39
Succinate	1.20	1.58	0.98	1.51
α-Ketoglutarate	1.21	2.65	1.27	2.56
Glutamate	1.77	2.53	1.44	2.54

1. Experimental conditions were as described in the text.

2. Each value represents at least six determinations.

Discussion

The data presented here suggests that 24 hours of physical stress is sufficient to markedly increase the metabolic rate of liver homogenates from EFA deficient rats. Furthermore, liver mitochondria isolated from stressed EFA deficient rats showed a pronounced increase in ATPase activity, loss of oxidative capacity, and respiratory control and uncoupled oxidative phosphorylation. Liver preparations from adequately nourished rats which had been subject to 48 hours stress showed the same aberrations but to a lesser degree.

The apparent conflict between the oxidative capacity of homogenates and isolated mitochondria from the four groups necessitates further discussion. The relative rates of oxidation by liver homogenates and mitochondria in the absence of a phosphate acceptor system are in good agreement. However, when a phosphate acceptor system is incorporated into the incubation medium, the highest oxidative rate was obtained with mitochondria isolated from unstressed, adequately nourished rats. These results are in direct opposition to those obtained with either liver homogenates or isolated mitochondria without a phosphate acceptor. Lardy (6) has shown that the rate of mitochondrial respiration is dependent on the availability of a phosphate acceptor system and that a maximum oxidative rate is obtained in the presence of such a system. Petrushka et al (7) found that treatment of rat liver mitochondria with phospholipase A resulted in an initial stimulation of the respiratory rate followed by a rapid decline which coincided with a breakdown in the mitochondrial structure. A decreased oxidative ability also occurs with mitochondrial swelling and intramitochondrial structural changes (8). The decline observed in the maximum

oxidative capacity of mitochondria isolated from EFA deficient and stressed control rats would suggest that these mitochondria are abnormally fragile and undergo structural damage, probably during the process of isolation. That this situation occurs in isolated EFA deficient mitochondria has been suggested by Levin (9) and substantiated by Smith and DeLuca (1).

The increase in the ATPase activity of the liver mitochondria isolated from EFA deficient rats, both stressed and unstressed, and the stressed control rats supports the concept that these mitochondria have sustained structural damage. Fresh, undamaged liver mitochondrial preparations possess little or no ATPase activity and show the highest degree of oxidative phosphorylation (10). Aging the mitochondria results in increased ATPase activity and reciprocal changes in phosphorylating activities. Both increased ATPase activity and extensive structural damage as revealed by electron microscope examination of thin sections have been reported in ETA deficient mitochondria (1). The loss of respiratory control observed in the present experiments could be the result of the increased ATPase activity and uncoupled oxidative phosphorylation.

It can be concluded from the present data that physical stress accentuates the biochemical defects observed in EFA deficient mitochondria. Furthermore, mitochondria isolated from adequately nourished rats which have been subject to 48 hours of physical stress exhibit the same properties as do the EFA deficient mitochondria but to a lesser degree. Since the structural fragility of EFA deficient mitochondria can be related to the lipid composition (1,11), investigation of the effect of stress on mitochondrial lipid composition is warranted.

An abstract of the data incorporated into this report has been submitted to the Federation of American Societies for Experimental Biology for presentation at the annual meeting. A copy of the abstract is appended.

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Nutrition

OXIDATIVE CAPACITY OF MITOCHONDRIA ISOLATED FROM STRESSED ESSENTIAL FATTY-ACID DEFICIENT RATS

Janet A. Smith* and Arnold Sodergren* (Spon: B. Poulton)
Univ. of Me., Orono, Me.

Rats which exhibited the symptoms of the essential fatty acid (EFA) deficiency syndrome were subjected to physical stress by being rotated in a motor-driven drum up to the limit of their endurance. After the stress period the rats were killed and the metabolic activity of isolated liver mitochondria was investigated using standard manometric techniques. Mitochondria from stressed EFA-deficient rats oxidized various of the Krebs cycle intermediates in the presence of phosphate acceptor at about the same rate as did those from unstressed EFA-deficient rats but at a much lower rate than did mitochondria from the control rats regardless of stress. This situation was reversed in the absence of a phosphate acceptor. In addition, mitochondria from stressed, EFA-deficient rats exhibited the highest ATPase activity of the four groups, a loss of respiratory control and an uncoupled oxidative phosphorylation. Liver mitochondria isolated from control rats showed similar but less severe effects of physical stress. These data would suggest that physical stress aggravates detrimental effect of an EFA deficiency on liver mitochondria and has a similar but less severe effect on mitochondria isolated from adequately nourished rats. (Supported by a grant from NASA)

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EFFECT OF METABOLIC RATE AND LOADING ON TEMPERATURE REGULATIONS AND SURVIVAL IN A HIGHLY CONDUCTIVE ATMOSPHERE - Dr. C. W. Major

Problem

The objective of the project is to determine whether changed metabolic rate or loading of rats exposed to a helium-oxygen atmosphere will significantly alter their thermal maintenance.

Experience in diving indicates helium can be substituted for nitrogen in the gaseous composition provided for astronauts. Helium has superior leak rate qualities, significantly prolongs the life of electrical components (due to its high conductivity), does not form significant radioisotopes with cosmic bombardment and may well be positively useful in reducing the danger of lung collapse.

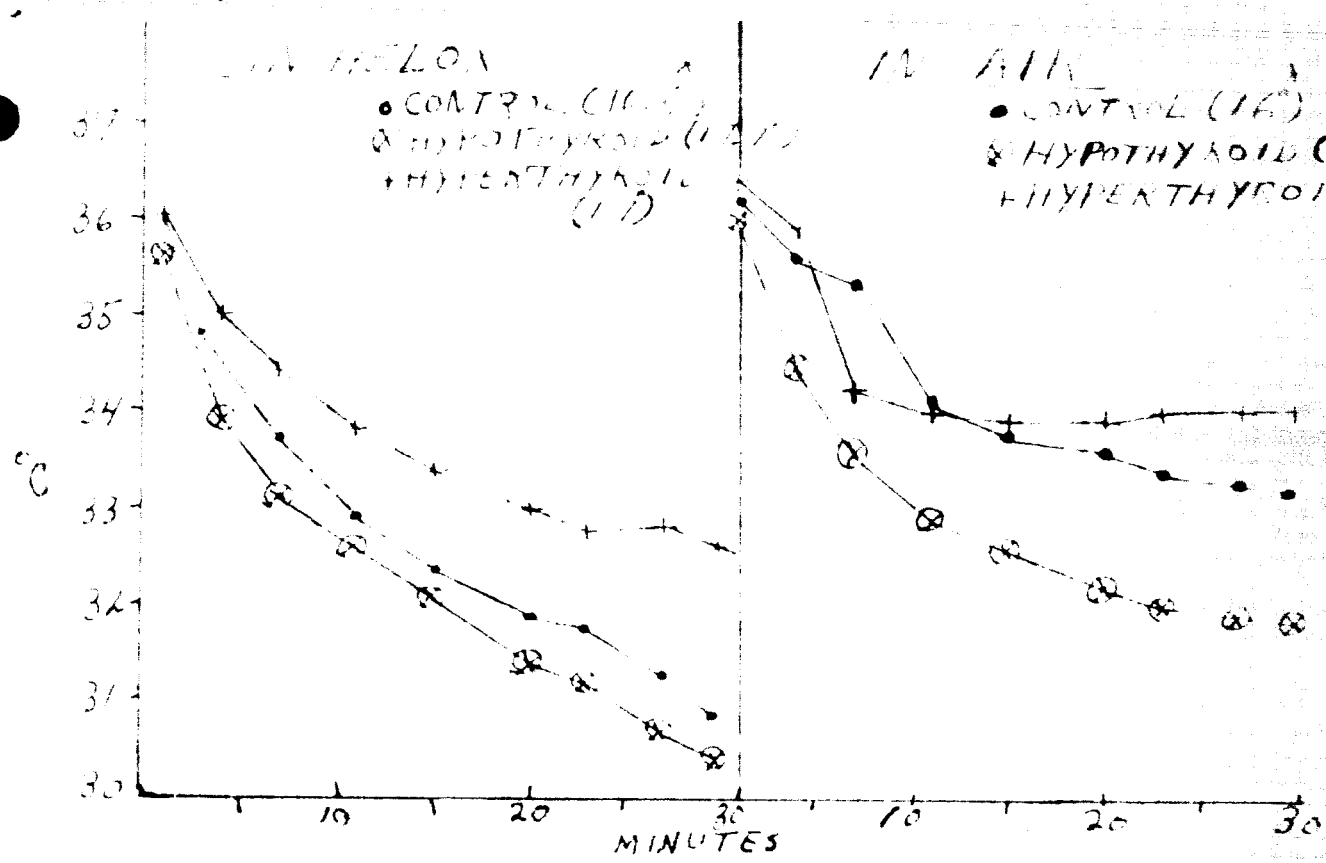
Certain biological problems do arise with helium. There is an octave shift in voice level (which can be corrected electronically) and the high conductivity causes problems in body temperature maintenance. If body metabolic rate or metabolic loading are increased in such an atmosphere will there be any significant new problems or advantages. It is proposed that body temperature regulation in rats exposed to such an atmosphere be studied in animals of varying rates of metabolism induced by manipulating thyroid hormone levels and to load these with forced intake of food both in the temperature loss state and with thermal maintenance or constant thermal conditions. In man one must go to about a 93°F environment to maintain body temperature. At this level food loading can well be a serious factor. Pilot experiments in this area indicate that this can be lethal in hyperthyroid rats.

Results

The rat is insulated to the point where only the respiratory tract and the tail may serve as effective heat loss surfaces. When restrained, the animal is closely equivalent to a restrained, suit-insulated astronaut. The rat, however, has evolved toward cold resistance with consequent heat sensitivity whereas man is normally heat resistant and cold sensitive.

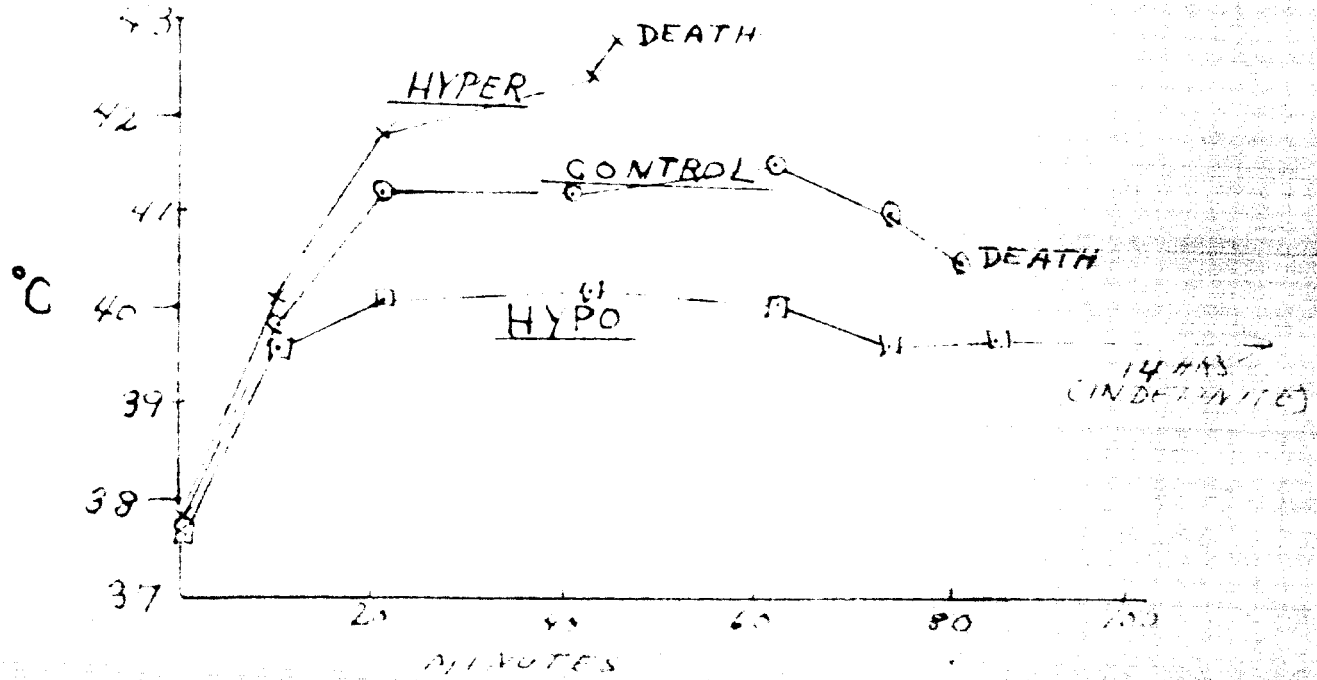
We have exposed rats to varied heat levels under varying metabolic states - hyperthyroid, hypothyroid, and normal. The gas environment has been either air of 80% helium-20% oxygen (HELOX). The animals do not survive temperatures above 38°C regardless of treatment. Death at these levels occurs in less than an hour with sudden change in respiratory pattern from rapid breathing to a slow gasping. In air with the ambient temperature at 36°C one reaches the point at which metabolic manipulation is possible. The hyperthyroid survived for 45 minutes, the control for 80 minutes, and the hypothyroid survived for 14 hours when the experiment was terminated. We will next run the HELOX at this temperature and work upward to see if the situation is better with the more highly conductive gas.

Exposure to a stream of cold gas, in the dark, in a small insulated chamber, gives a good indication of resistance of the animals to cold stresses. In our test chamber, with air as the gas phase and the temperature at 22°C, we found only minor rectal temperature changes in all metabolic groups. Under the same conditions with HELOX there was a rapid temperature drop in all the groups with the hypothyroid group showing the greatest and most rapid decline. We have extended this to 15-17°C and in this zone there is a rapid temperature decline in both HELOX and air. In all of these situations the hypothyroid is the most sensitive and the other two groups are less distinct. The control and hyperthyroid groups in air show a tendency to stability after an initial drop. In the HELOX this pattern is seen in the hyperthyroid.



EXPOSURE TO COLD GAS STREAM (10-18°C)

* MEAN AMBIENT DURING RUN



HEAT EXPOSURE AT 36°C AMBIENT (AIR)

UNIVERSITY OF MAINE SPACE SCIENCE LECTURE AND CONSULTATION SERIES - Dr. B. R. Poulton

Proposal

Eminent persons involved in space science and technology at the national level will be invited to Maine to interact with the University community in a variety of ways. There would be lectures of interest to the general faculty and the student body, seminars for NASA trainees and investigators involved in NASA sponsored research, and opportunity for extended discussion on an individual basis.

By the lecture series, we hope to increase interest among students and faculty in space science and technology, and to assist researchers and students now engaged in these areas.

Report of Progress

The first lecture in this series was held on December 9, 1965. Dr. Roy Talmage of Rice University in Houston, Texas was the speaker. Dr. Talmage's formal lecture was on the topic of calcium and its metabolic importance. In his lecture Dr. Talmage dealt with some of the aspects of bone demineralization as it might be related to physical stress such as weightlessness. While Dr. Talmage was on campus, he held conferences with a number of the staff who are currently working on space science research projects. Dr. Talmage also consulted with several graduate students and other members of the general university research community.

The second lecture was presented on January 4th by Dr. Stephen Brush, Physicist, Harvard University. Dr. Brush's formal lecture was on the subject of rarefied gas dynamics. His lecture dealt specifically with the properties of rarefield gases, their effect on the lift and drag of an object of a given shape moving at a given speed. In his presentation Dr. Brush related much

of our knowledge of rarefied gas dynamics to original experimentation carried out on the radiometer. While on campus Dr. Brush also presented another lecture and a seminar for the chemistry group. Additionally he consulted with a number of the members of our research community.

Additional lectures planned for this academic year will be in the area of human behavior related to space travel, bio-engineering, lunar geology and a more general lecture on the future of space travel.

A BIO-ENGINEERING STUDY OF THE EFFECTS OF CO_2 STRESS ON THE PHYSIOLOGY AND NUTRITION OF ANIMALS

Dr. William H. Hoover, Principal Investigator
Dr. Bruce R. Poulton, Co-Investigator

Department of Animal Sciences

Dr. Edmund M. Sheppard, Principal Investigator
Prof. Carleton M. Brown, Co-Investigator

Department of Electrical Engineering

General Statement

The problems involved in respiration physiology in manned spacecraft have recently been reviewed (DuBois et al. 1963). Carbon dioxide pressure in the capsule environment is known to affect arousal state, performance level, radiation sensitivity, anoxea, and acclimatization to temperature variations and changes in the partial pressures of atmospheric gasses.

In a more recent review, (Roth 1964) E. M. Roth reported that beginning at partial pressures of 20 mm Hg of CO_2, certain biochemical adaptations take place in man, and that beginning at partial pressures of 60 mm Hg of CO_2 pathological changes are encountered. Roth further generalized that 6 to 10% CO_2 in the air represents the zone of distressing discomfort and beginning at 10% CO_2, dizziness, stupor and unconsciousness are encountered.

Although a vast amount of information is available on the physiological effects of CO_2 on man and animals, there are a number of areas of importance to the space effort which require attention.

The effects of CO_2 on the nutritional state (voluntary food intake and food digestibility) of animals and man have not been thoroughly investigated. There are indications in the literature that CO_2 may influence carbohydrate metabolism (Shaefer et al. 1954, 1955) and passage of food

through the digestive tract (Cordier and Chanel, 1950 and Danhoff, 1954).

Another area requiring investigation involves the effects of long-term CO_2 exposure (of a week or more) at CO_2 levels ranging from atmospheric conditions to as high as 20%. This type of study would facilitate collection of valuable information on the animals' desire to consume food and food digestibility, on the extended physiological responses, on histopathological changes in the tissues and on blood metabolite balance.

The first studies by the Department of Animal Sciences were initiated in 1963 by W. H. Hoover and B. R. Poulton. The project was entitled "Effects of increasing the CO_2 tension of inspired air on nutrient intake and digestibility". The objectives of this project were to investigate the effects on nutrient intake and digestibility of exposing animals to CO_2 levels of 4, 8, 12, 16 and 20% for a period of seven days.

Experimental Procedure

Conduct of this experiment required construction of an open-circuit respiration chamber and purchase and installation of the related equipment needed for measuring air flow, air sampling and analysis, and metering CO_2 into the chamber. A photograph of the chamber appears in figure 1, and of the gas analysis equipment in figure 2.

The chamber was designed to facilitate the use of sheep as the experimental animals. Sheep were chosen because they are similar to man in metabolic size, basal metabolic rate and cardiac rate.

Wether sheep weighing 130 to 150 lbs were used. Each animal served as its own control, being placed in the chamber for a period of seven days at normal atmospheric conditions. Chopped hay was fed and intake recorded. Feces were collected for digestibility determinations. Immediately following the control period, bottled CO_2 was admitted to the chamber through a

flow control valve, which enabled maintenance of a constant CO_2 level within the chamber. Compressed CO_2 was used in an attempt to maintain high CO_2 levels with a minimal decrease in O_2 tension. The exhaust gas from the chambers was metered and sampled continuously by spirometers, and analyzed by either a Carpenter-Haldane apparatus or a Fisher-Hamilton gas partitioner. The feed and feces were analyzed by proximate analysis techniques for digestibility determination.

Experimental Results

Thirteen trials at 4, 8, 12, 16 and 20% CO_2 have been completed. A summary of the intake data appears in table 1, and of the protein and energy digestibilities in table 2.

Table 1. Feed Intakes at varying levels of Carbon Dioxide as a percent of the Control Intakes.

Carbon Dioxide Concentration %	Oxygen Concentration %	Trial Number 1	2	3	4
4	19.8	104.5	97.1	128.4	-----
8	18.8	96.6	89.1	102.6	89.9
12	-----(a)	76.5	46.6	40.6	-----
16(b)	17.5	89.2	88.1	-----	-----
18	-----(a)	14.2	-----	-----	-----

(a) Oxygen concentrations were not determined as the Fisher-Hamilton partitioner was malfunctioning and the Carpenter-Haldane apparatus cannot determine oxygen concentrations at these high carbon dioxide levels.

(b) The apparent increase in intake over the 12% level is thought to result from an acclimation period introduced at the 16% level.

Table 2. Comparison of the Proteins and Energy Digestibilities at the various Carbon Dioxide Levels Expressed as a Percentage of the Control Periods.

Carbon Dioxide Concentration	Protein Digestibility Trial Number				Energy Digestibility Trial Number			
	1	2	3	4	1	2	3	4
%								
4	-2.87	∤3.00	----	----	-2.12	-6.29	----	----
8	∤4.99	∤3.00	-1.83	----	∤3.18	∤5.06	-3.09	----
12	-0.03	-0.08	----	----	∤0.77	∤0.05	----	----
16	∤2.18	-20.22	----	∤4.81	∤1.79	∤16.78	----	∤7.76
20	----	----	----	-16.86	----	----	----	-17.84

When exposed to 4% CO_2, appetite increased in several cases. No effect on ventilation rate was noted. At the 8% carbon dioxide level, the animals became distressed for a short period as indicated by hyperventilation.

The 12 and 16% carbon dioxide levels resulted in more marked hyperventilation and lower feed intakes in all cases. In several trials, however, the animals appeared to become acclimated to this atmosphere with a return to a more normal ventilation rate. Upon return to a normal atmosphere the animals exhibited a period of listlessness and lowered feed intake for about 24 to 36 hours.

One sheep was exposed to 20% carbon dioxide for 5 days. This animal showed marked hyperventilation and low feed intake as well as a weight loss of 15 pounds.

One mortality was incurred during the experiment at the 16% level. An autopsy revealed massive hemorrhages in the heart, lungs and kidneys.

The animals appeared more able to withstand the higher carbon dioxide levels if the levels were increased gradually rather than abruptly. The following conclusions appear warranted:

1. The animals can survive, for periods of at least one week, at levels as high as 20% CO_2.
2. At levels of 12% CO_2 and above marked physiological changes can be observed.
3. The most obvious effects are increased respiration rate, decreased feed intake and decreased alertness.
4. There are some indications that a gradual increase in CO_2 level to concentrations of 12% and above have less severe physiological effects than abrupt exposure.

This work is currently being prepared as a thesis for the degree of Master of Science by Mr. P. H. Knowlton. A manuscript for publication will subsequently be written.

Current Research

In February, 1965, a project entitled "A bio-engineering study of the effects of CO_2 stress on the physiology and nutrition of animals" was undertaken by Dr. W. H. Hoover and Dr. B. R. Poulton of the Animal Sciences Department, and Dr. E. M. Sheppard and Prof. C. M. Brown of the Electrical Engineering Department. The direction of the present research effort was suggested by the results of the previous project, which indicate that animals may have the ability to adapt to high levels of CO_2, providing the increase in CO_2 concentration is gradual rather than abrupt. The major objective of the proposed study was to subject this possible adaptation response to a more critical examination, using both nutritional responses of intake and digestibility and physiological responses of heart rate and respiration rate as criteria.

Continuous monitoring of the physiological responses of an animal inside a respiration chamber for 7 days presented challenging engineering

problems. In addition, a respiration chamber which would permit access to the animal during the experimental period was required.

The initial problem, that of measuring the physiological responses, is near solution. Professors Sheppard and Brown have been successful in obtaining an excellent ECG for an extended period of time by means of electrodes implanted beneath the animals skin (see figure 3).

The more difficult project of determining the respiration rate of an unrestrained animal has also been accomplished. The basic principle employed here was placement of a thermister in the nasal passage of the animal which would detect the temperature difference between inhaled and exhaled air. It was learned early that this method worked in principle, but keeping the thermister in place was a problem. This problem was solved by means of a surgically implanted plastic fistula through which the thermister may be inserted and held in place. A photograph of a sheep with the nasal fistula is shown in figure 4.

The engineering problems remaining for Professors Sheppard and Brown are concerned with data handling and reduction, and chamber instrumentation.

A respiration chamber which will permit access to the animal during the experimental period has been constructed in the Animal Sciences Department. It contains an air-lock, which will permit access to the chamber without opening the main chamber to room air. The person entering the chamber will wear a face mask and breathe room air through an intake hose. The exhaled air will also be exhausted to the room. A photograph of the new chamber is in figure 5.

Experimental procedure

This phase of the investigation will be divided into two periods. In the first period control information will be collected on each animal

in the chamber for a period of seven days. Then, using three animals at each CO_2 level, the animals will be abruptly exposed to levels of 2, 4, 8, 12 and 16% CO_2 for a seven-day period.

In the second period again using three animals at each CO_2 level, sheep will be exposed to CO_2 gradually increased to levels of 4, 8, 12, and 16%. The rate of CO_2 increase will be adjusted to require approximately three days to reach each respective level, where it will then be held for an additional seven-day data collection period.

Future Plans

A proposal for additional funds to broaden the objectives of this research has been made directly to the National Aeronautics and Space Administration. This proposal entitled "A Bio-Engineering Study of the Effects of Carbon Dioxide Stress on the Physiology and Nutrition of Animals" was submitted in July, 1965. It is a combined effort of the Animal Sciences and Electrical Engineering Departments with assistance from the Animal Pathology Department. The objective of this proposal are:

1. To develop instrumentation capable of measuring and recording cardiac rate, respiration rate and alertness of animals isolated in respiration chambers for continuous periods of seven to ten days.
2. To study the effects on respiration rate and heart rate of exposing animals both instantaneously and gradually to CO_2 levels of 2, 4, 8, 12, 16, and 20% for a period of seven days.
3. To study the effects of the specific CO_2 exposures on the intake and absorption of protein and energy and to supplement these observations with studies on the passage of food in the digestive tract, and the levels of certain metabolites associated with appetite (blood glucose, blood volatile fatty acids).

4. To study the effects of exposure at specific CO_2 levels on respiratory exchange.
5. To perform complete necropsy examinations on animals immediately following their CO_2 exposure and to observe any gross organ changes supplemented with appropriate histological and histochemical studies.
6. To develop data acquisition and handling systems to support the other objectives of this study.

PROGRESS REPORT JANUARY, 1966

Project Title: A Bio-engineering Study of the Effects of CO_2 Stress on the Physiology and Nutrition of Animals
NsG 338, R1083-23

Departments: Animal Sciences and Electrical Engineering

Principal Investigators: W. H. Hoover, Animal Sciences
E. M. Sheppard, Electrical Engineering

Co-Investigators: B. R. Poulton, Animal Sciences
C. M. Brown, Electrical Engineering

Supplement to Report Submitted October, 1965

The respiration chamber and related equipment constructed by the Animal Sciences Department has recently undergone testing and modifications and is now ready for the initiation of experimental work.

Work on instrumentation procedures by the Electrical Engineering Department is in the final phases and will be reported on by Dr. Sheppard.

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THE DIMENSIONALITY AND COGNITIVE DEMANDS OF CERTAIN SCIENCE AND MATHEMATIC PROBLEMS AND THEIR RELATIONSHIPS TO CONVERGENT AND DIVERGENT THINKING TASKS AND ANXIETY - Drs. F. W. Ohnmacht, G. T. Davis and John Lindlof

Proposal

The present investigators start with the assumption that achievement in both science and mathematics is multi- rather than unidimensional and that the various dimensions differ in terms of the complexity and quality of thought required of subjects and that such differences are of some importance in both the prediction of success in and the selection of students for various curricula. Of even more fundamental importance is the possibility of an improved understanding of the nature of abilities required and the processes utilized by subjects in the solution of mathematics and science problems. The present study would attempt to determine the dimensionality of two widely used achievement tests in the mathematics and science areas and to what extent each dimension is related to a sample of convergent and divergent thinking tasks as well as generalized anxiety. Furthermore, the study would attempt to gain insight into what is required of subjects to answer problems sampling the dimensions obtained.

Results

Some Initial Surprises. While not a direct goal of the present study, to date, some of its most profitable outcomes have resulted from serendipity. That is, in searching for one thing, other things of equal or possibly greater value have been found. On the one hand, we have obtained computer programs (Moore & Ross, 1964) in far off Australia which have reduced the machine time needed for the factoring of large matrices by from one-quarter to one-third of the time needed with the programs previously available. This is no small saving since with the Australian program we have managed

to utilize approximately 100 hours of machine time. On the other hand, certain theoretical questions involving the preparation of items for factorization have presented the investigation with undesired but rather interesting problems.

Since the test items are dichotomized (right or wrong) the tetrachoric correlation is the appropriate index of relationship to insert in the matrix of correlations among the items to be factored. Carrol (1944) presented the rationale and formulae for correcting 2 x 2 tables for chance success prior to computing the tetrachoric correlation. Presumably this procedure yields a superior estimate of the true factorial overlap between items. Despite the widespread acceptance and repetition of Carrol's recommendation to correct tables prior to computing tetrachorics for purposes of factorization, it seems that it has not been well-heeded. We have been unable to locate in the literature a single instance of its application! In part, this is probably due to the recency of high speed digital computation aids since the whole procedure is exceedingly laborious. But, in our case at least, other problems seem to be confounded within the domain of our original concern.

For the factor analysis of mathematics items it was decided to utilize corrected tetrachorics in the matrix to be factor analyzed. This decision resulted in a correlation matrix which yielded a Haywood Case, i.e., one or more communalities were greater than one. Kaiser and Coffrey (1965) have argued that when this situation arises that the offending communalities be allowed to converge to values greater than one on the grounds that this merely implies that a variable's unique part has negative variance. Put in another way, the variable's unique factor scores are imaginary. Common

factor scores for the variable would still retain their integrity. They present no data to support their view. This, of course, raises the question of the comparability of factor structures obtained using corrected and uncorrected matrices produced from the same data. If they are comparable, why bother to correct? At this point, the question is unresolved, but it is hoped that one of the two sets of data available in the present study will be subjected to analysis of both the corrected and uncorrected matrices and the resulting factor structures compared.

Mathematics Test Analysis. The first analysis was performed on the 32 items of the Stanford Achievement Test with the addition of two measures of convergent thinking (Verbal and Non-Verbal scores of the Large Thorndike Intelligence Test), two measures of divergent thinking (Word Association and Uses for Things) and a measure of Manifest Anxiety. The matrix which was factored consisted of corrected tetrachorics, with the unities in the main diagonal. The principal axes method of factor analysis was employed and factoring ceased when the latent root associated with a component was less than one following the recommendations of Kaiser (1960a,1960b). All components meeting the criterion of having a root of one or more were retained and rotated to the varimax criterion (Kaiser, 1958).

Fifteen components met the latent root criterion and after rotation it was apparent that a substantial number of these were either unique (a factor with only one variable representing it) or doublets (factors with two variables representing them). Three unique factors and seven doublets were obtained. None of these factors is deemed as significant and will not be considered in successive stages of the study.

Of the remaining five components, two are represented by three variables. These components account for but a small amount of the total variance and will also be deleted from successive stage. This leaves three broad group factors which have 12, 10 and 9 variables representing them (loading of .50). One of these factors is a rather general factor with substantial loadings for Verbal and Non-Verbal I.Q., Word Association as well as a number of mathematics items. The other two factors represent two other major dimensions underlying the mathematics items. Their interpretation awaits the completion of successive stages.

As an empirical matter, measures representing anxiety, chronological age, and one aspect of divergent thinking (Uses for Things) are essentially independent of the three large group factors. In each case the variables cited were identified as unique factors. In addition, it can be said the mathematic sub-test is clearly not unidimensional and a description of content of the test requires at least three dimensions as represented. This is, of course, not the way the test is scored. The usual method of totaling up the number correct implicitly assumes a unidimensionality underlying the item content. This assumption is clearly not tenable in the present case.

Science Test Analysis. The analytic procedures previously described were also applied to the science test items of the Stanford Achievement Test. One exception was made in that uncorrected tetrachorics were employed with the hope that another analysis could be undertaken using corrected coefficients. In any event the results clearly indicate that the datapool is multidimensional. Since these results have just come to hand, little more can be said at this time.

The Future

Present plans call for the formulatinn of an interview schedule which will contain items representing the various factors uncovered. Verbal responses of elementary school Ss will be content analyzed to ascertain if items representing said factors elicit differential responses with regard to selected aspects of divergent production, as well as identifying strategies employed by the respondents.

A STUDY OF ATTITUDES CONCERNING DEATH - Dr. G. M. Vernon

Problem

Research in the behavioral sciences has progressed rapidly. However, there remain several "islands" of behavior which have received but little attention. Attitudes toward death is one such area. The major objective of the proposed research is to secure scientific information about such attidues and other related behavior including procedures used to adjust thereto. We need to know not only specific attitudes toward death, but also the configuration of social correlates of which each is a part. Findings would be related to established theories of human behavior and would be scrutinized hypotheses for more extensive future study.

In the space program any fear of death is compounded by the fear of the unknown. It is well established that concern with problems not directly connected with occupational tasks influences the performance thereof. Limited research has already indicated that removing some of the taboo aspect from the topic by talking about it tends to reduce associated tension.

It would seem that the more we can learn about attitudes toward death the more effectively we can function in situations such as the space program.

Results

Attached is a copy of the research instrument, that is a questionnaire, which has been developed.

DEPARTMENT OF SOCIOLOGY AND ANTHROPOLOGY
UNIVERSITY OF MAINE

This study investigates the reactions which people have to death. Even though most people have had experiences relating to death, very little research of this nature has been done. It is felt that much benefit could result if the general public and the social scientist both had more knowledge of what people actually think about various aspects of death. You are requested to help us in achieving this goal by answering the following questions. You are not asked to provide your name. You are requested to indicate the answer to each question which most accurately reflects your personal feelings.

Thanks for your help. The questionnaire should be returned to:
Dr. Glenn M. Vernon, Head
Dept. of Sociology and Anthropology
University of Maine, Orono, Maine

1. Under which of the following conditions do you experience the greatest grief?
   ___1. When first notified of the death
   ___2. When viewing the deceased at the wake or funeral home
   ___3. During the funeral service in a chapel or church
   ___4. At graveside service
   ___5. After burial
   ___6. Other. (Specify)_____

2. How frequently do you think of your own death?
   ___1. Very rarely ___2. Rarely ___3. Occasionally ___4.Frequently ___5. Very frequently

3. Under what special circumstances, if any, do you most often entertain thoughts of your own death?_____
   _____

4. If you knew positively that there was no life after death in store for you, do you think that your manner of living in the present life would be changed?
   ___1. Very little if any change
   ___2. Slight change
   ___3. Considerable change
   ___4. Extensive change

5. Do you feel that you could currently adequately face the death of a loved one?
   ___1. Yes ___2. No ___3. Undecided

6. Please indicate which of the following best expresses your concept of immortality
   ___1. Biological (through one's children)
   ___2. Social (through work accomplishments that live on in the thoughts of the living)
   ___3. Transcendental (belief that life is but the pre-condition of the "true" life yet to come)
   ___4. Don't believe in immortality of any sort. Death is the end.
   ___5. Other. (Specify)_____

7. What have you done to prepare yourself for your eventual death?_____
   _____
   _____

8. Do you have a strong wish to live after death.
   ___1. Yes ___2. No ___3. Undecided

This research is supported by NASA Research Grant No. NsG-338, Univ. of Maine.

9. Please indicate the relative importance of the following items in terms of any fears you may have concerning death by placing the number "1" in the blank preceding the item you fear most about the death experience; the number "2" for the next in order of decreasing intensity:

___1. I could no longer have any experiences
___2. I am uncertain as to what might happen to me if there is a life after death.
___3. I am afraid of what might happen to my body after death
___4. I could no longer care for my dependents
___5. My death would cause grief to my relatives and friends
___6. All my plans and projects would come to an end
___7. The process of dying might be painful

10. Have you ever seriously discussed the subject of death--not in reference to a specific incident or disaster, but as a general concept which applies universally to all human beings?

___1. Yes ___2. No

IF "NO", would you desire to do so?

___1. Yes ___2. No ___3. Undecided ___4. Later in life.

11. It has been suggested that a unit of study on the "mental hygiene of grief" be developed and taught in our schools, much the same way that physical hygiene is taught. What do you think of this idea?

___1. I agree that this should be done
___2. I disagree. Since grief is such a personal experience, each must handle it in his or her own way.
___3. I disapprove of burdening the young with such morbid subject matter.
___4. I don't feel I've considered this subject sufficiently to express an opinion concerning it.

12. Please specify any experiences which you feel have significantly modified your attitudes toward death._____

_____

_____

13. How many times have you actually seen a dead body before it was prepared by the mortician?

___1. Never ___2. Once ___3. Twice ___4. Three or more

14. How many times have you seen a dead body after it was prepared by a morticiah?

___1. Never ___2. Once ___3. Twice ___4. Three times or more

15. In the matter of disposal of the corpse, certain classes of the dead are sometimes denied the usual rites or customary treatment (place of burial, etc.) accorded to the majority of the members of a society. Do you feel any differentiation is warranted in these matters?

___1. In some cases
___2. No. I see no basis for any differentiation after death.
___3. Yes, because society's value systems are thus reinforced and this may serve, in some cases, to diminish the probability of deviant behavior,etc.
___4. Yes, because of economic factors such as public expense, available burial area, etc.

16. Do you approve of cremation for others?

___1. Yes ___2. No ___3. Undecided

17. Would you approve of cremation for yourself?

___1. Yes ___2.No ___3. Undecided

18. Does the question of a future life worry you considerably?

___1. Yes ___2. No ___3. Undecided

19. Would you prefer to know about the future life positively, or would you prefer to have it left a matter of faith or belief?
___1. Know Positively ___2. Left to faith or belief.

20. Which of the following best expresses your concept of why death is universal and inevitable for all human beings?
___1. Death is the natural end of all living organisms
___2. Death is a punishment of mankind for the transgression of a divine law.
___3. Other(specify)_____

21. Do you feel that religious observances by the living can somehow benefit the state of those already dead?
___1. Yes ___2. No ___3. Undecided

22. Is it your personal belief that there will be a future existence of some kind after death?
___1. Yes ___2. No ___3. Undecided

23. Which of the following best describes your general reaction when you think most seriously about God.
___1. Strong fear
___2. Moderate fear
___3. Slight fear
___4. No fear

24. Some believe the individual can conceptualize the death of others, but not his own death. Which of the following statements comes closest to what you believe?
___1. This is true in my own experiences
___2. I feel I can conceptualize my own death
___3. I never think about my own death, except perhaps in reference to provisions for my survivors
___4. I never think about my own death
___5. I actively avoid thoughts about my own death.

25. Do you approve of the custom of open-casket viewing of the deceased?
___1. Yes ___2. No ___3. Undecided

26. In your past experiences, at what age do you recall having the greatest fear of death?
___1 to 5 years of age
___5 to 10
___10 to 15
___15 to 20
___20 to 25
___ 25 to 30
___30 to 35
___ 35 to 40
___ over 40

27. Have funeral arrangements (for those now living) been discussed in your family?
___1. Yes ___2. No ___3. Don't know.

28. If you have ever experienced bereavement, did you feel
___1. constrained to conform to socially expected expressions of grief, sometimes not in accord with your true feelings
___2. the expected behavior patterns for this period satisfied your needs
___3. an indescribe "numbness" which made you unaware of your behavior so that you cannot describe it
___4. Never experienced bereavement

29. If you met someone who had lost a loved one through death since your last encounter with this person would you
___1. Mention the death
___2. Wait for them to mention the death
___3. Prefer that no mention of the death be made by either party
___4. Never considered this situation before, and do not feel prepared to answer one way or the other.

30. Do you approve of mercy killing in cases of extreme suffering?
___1. No
___2. In some cases
___3. Only if the lethal agent is self-administered or requested by the patient

31. How would you prefer to die?_____

_____

32. What do you consider to be a reasonable price to pay for funeral services (all inclusive: embalming, casket, funeral director, service, burial, burial plot, etc.)

___$100 - $300
___ 300 - 600
___600 - 900
___ 900 - 1200
___1200 - 1800
___1500 - 2000
___over $2000

33. Do you feel that if an individual is dying and is beyond any available medical aid, that it is more desirable to remove the person to a hospital or other institution, rather than have them remain at home?
___1. Yes, this is the best course for all concerned
___2. No. Death should be at home, if at all possible
___3. Undecided

34. If you contracted a fatal illness, do you feel you would want to be told that you would most likely die?
___1. Yes ___2. No ___3. Undecided
(Optional) Why?_____

35. Do you feel that capital punishment is warranted under any circumstances?
___1. Yes ___2. No ___3. Undecided.

36. If arrangements for the funeral of a family member were left up to you, which of the following would you most likely consult first?
___1. A clergyman
___2. Funeral Director
___3. One of your close friends
___4. A close friend of the deceased

37. Which of the following best described you?
___1. Death was never explained to me
___2. I don't have any memories of being exposed to death in my childhood
___3. My questions were generally answered to my satisfaction

38. How would you prefer to be treated if you were mourning?
___1. Be left alone with my own thoughts
___2. Prefer to receive expressions of sympathy of those around me
___3. Undecided
___4. Other (Specify)_____

39. Have your religious experiences in general served to increase or decrease fear toward your own death?
___ Increase fear
___ Decrease fear
___ No influence

40. Do you anticipate reunion with your loved ones in an afterlife?
___1. Yes ___2. No ___3. Undecided

41. Have you ever had a feeling that you were somehow in the presence of God?
___1. Yes, I'm sure I have
___2. Yes, I think that I have
___3. No

42. Have you ever had a feeling of being punished by God for something you have done.
___1. Yes, I'm sure I have
___2. Yes, I think I have
___3. No

43. Which of the following statements comes closest to what you believe about God?
___1. I know God really exists and I have no doubts about it.
___2. While I have doubts, I feel that I do believe in God.
___3. I find myself believing in God some of the time, but not at other times
___4. I don't believe in a personal God, but I do believe in a higher power of some kind.
___5. I don't know whether there is a God and I don't believe there is any way to find out.
___6. I don't believe in God.

44. What is your evaluation of the statement that the devil actually exists.
___1. It is completely true
___2. It is probably true
___3. It is probably not true
___4. It is definitely not true

BACKGROUND INFORMATION

1. Age_____ 2. Sex_____
3. ___Married___Single___Divorced___Separated___Widowed
4. Religious affiliation (Please give the specific name of your religious group--not just "Protestant", etc.)_____
5. How would you describe your health history:
___Excellent ___Generally good ___Average ___poor
6. If you consider yourself to be either a Democrat or Republican, indicate which
___Democrat ___Republican
7. Are you a veteran? ___Yes ___no
8. Religious affiliation of your parents
Father_____Mother_____
9. Occupation of husband (of father for students)_____
10. Estimated family income for 1965 (College students answer for your parents' income)
___Under $5,000
___5,000 to 7,500
___7,500 to 10,000
___10,000 to 15,000
___15,000 to 25,000
___Over $25,000

Please add any comments you may desire.

A RESTRAINING DEVICE FOR USE IN THE MEASUREMENT OF EYELID RESPONSES IN LABORATORY RATS

Harvey C. Ebel

University of Maine[1]

APPARATUS

In studies of classical conditioning the behavioral attribute which is measured is, generally, a relatively restricted member of a class of response events which is effected by the unconditioned stimulus. Specifically, one might wish to isolate a particular system such as the eyelid response to a corneal air puff. One currently popular way to measure this relatively minute skeletal movement is to link some type of transducer directly to the eyelid of the organism and, either fix the transducer to the head of the organism (as is typically done with larger Ss, such as humans), or mount (i.e., physically ground) it external to S. In the latter case, the 'noise' problem created by slight head or body movement can readily produce recording artifacts. The technical problem, then, is total immobilization of the beast in order to prevent confounding responses.

A survey of several of the attempts to successfully obtain such a restrictive condition with animals, particularly with laboratory rats, gives some indication of the difficulties associated with imposing considerable restraint while permitting the examination of conditioned behavior.[2] Hughes and Schlosberg (1938) and Biel and Wickens (1941) utilized devices which, apparently, were insufficient to prevent the contribution of head, shoulder, and backward bodily movements to eyelid response protocols. Lykken and Rose (1959) developed a device, incorporating Ace-bandage wrap, which was intended for use with GSR recording in rats and which likewise permitted considerable head movement. There exists a variety of other techniques directed at permitting the measure-

ment of classically conditioned responses in animals, however, the majority of them (e.g. Cowles & Pennington, 1943; Haggard & Thompson, 1954) have neither attempted, nor succeeded in obtaining, total immobilization. One noteworthy exception, is a device described by Schneiderman, Fuentes and Gormezano (1962) for the recording of eyelid and eyeball movements in the albino rabbit.

The present note describes a means of restraining the laboratory rat (see Fig. 1) in order to permit measurement of the eyelid response; one which eliminates head and body movements which would otherwise be superimposed on the response record.

The animal rests upon a platform (see Fig. 2) with its legs hanging freely through four appropriately placed holes. Gross body movements are restricted by foam-lined U-clamps lowered around the body and over the forelegs. These clamps are secured in position with thumbscrews set in a bar mounted along the longitudinal axis.

A plexiglass device consisting of a 5/32-in. hole to locate and fix the position of S's upper incisors, a bite-board to support the upper jaw, and holes to receive the tips of a padded snout U-bolt, is also illustrated in Fig. 2. This unit is combined with the snout U-bolt and a similarly padded U-bolt behind the neck to immobilize the head region while retaining access to S's eyes. Wing nuts secure the snout U-bolt on the underside of the platform.

During research with the classically conditioned eyelid response, the entire platform is housed in a sound-deadened chamber, and supported within the chamber by means of foam-padded runners. The apparatus for

recording eyelid movements consists of a microtorque potentiometer, of the type described by Spence (1953), which is mounted beside S on the restraining platform. A rod is mechanically coupled to the shaft of the potentiometer and and free end attached to S's upper lid structure by means of a drop of flexible collodion. The signal from the potentiometer, generated by movement of the eyelid, may readily be amplified and recorded. In the course of conditioning (e.g., see Fig. 3), Ss have remained under restraint with little apparent discomfort for periods up to 90 min.

One serviceable feature of this apparatus is that, in contrast to techniques which require that S's legs be tied and made immobile (which may induce vascular damage), the present method allows such freedom of restriction of the legs that a similar use of a potentiometer may be applied for the measurement of limb responses (e.g., Caldwell & Werboff, 1962). The present author also notes that it is his experience that, with practice, less than 1 min is required to secure S, thereby allowing the use of a light anesthetic such as ether for "strapping-in."

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FOOTNOTES

[1]The original development of this apparatus was undertaken while HCE was a National Institute of Mental Health Predoctoral Research Fellow at Pennsylvania State University. Later work was supported in part by the National Aeronautics and Space Administration (Grant No. NsG-338).

[2]See Hall, Clayton and Mark (1966) for references to restraining devices related to studies of operant behavior.

Fig. 1. Rat is shown completely restrained just prior to the placement of potentiometer rod on eyelid.

Fig. 2. Restraining device for use in the measurement of eyelid responses in laboratory rats.

Fig. 3. Response probability in 20-trial blocks for subjects (n=7) receiving PAIRED CS-US presentations, and for subjects (n=8) receiving MIXED, unpaired CS and US presentations. Differences in mean response probabilities over blocks of trials are significant with $p < .01$ ($F=10.40$, $df=1,13$).

NASA GRANT NsG-338

Application for Funds from

University Space Research Committee

Principal Investigator: Dr. Harvey C. Ebel, Asst. Professor of Psychology

Date: January 31, 1966

Title: Classical Eyelid Conditioning in Rats

Sponsoring Instituion: The University of Maine

The present report describes activity and status of the project (Classical Eyelid Conditioning in Rats: Bioelectric Correlates) in the period from June 1965 to December 1965.

Summary:

A. Modifications of a restraining device in order to permit free access to the cranial region for the purpose of electrode placement during conditioning were completed. Such modifications will allow monitoring of evoked potentials from selected areas of the rat cortex as well as stimulation of selected sub-cortical areas via microelectrode or micropipet placement, during the course of conditioning. A copy of the related apparatus note (Ebel, 1966), which has been accepted for publication, is enclosed.

B. Four male Wistar rats, trained for six consecutive days, showed small increases in the probability of conditioned eyelid responses over sessions. Overall response levels were considerably lower than those obtained previously (Ebel, 1965) with a buzzer, rather than a pure tone, as a conditioned stimulus. Preliminary analyses indicated some changes in food intake and a general loss in muscle tone over the same six-day period. Substantial intrasession response decrements were particularly noticable over the final two days of the training regimen.

C. Six male Wistar rats were randomly assigned to one of two groups. Group L (n=3) received fifty paired presentations of 600-cps tone at a sound pressure level of 85 db (re: .0002 dynes/sq. cm.) and corneal air-puff, and fifty unpaired (i.e., no air-puff) presentations of a 1500-cps tone. Paired and unpaired trials were presented in an unsystematic order, each day, for five consecutive days. Group H (n=3) received fifty paired presentations of the 1500-cps tone and fifty unpaired presentations of the 600-cps tone in a program otherwise identical with that of Group L. No differential responding to the two stimuli was observed during this discrimination training, interms of response probability. Preliminary analyses indicate, however, that responses to the paired stimulus (S+) and the unpaired stimulus (S-) could be differentiated on the basis of response latency and puff avoidance. Specifically, response latency to S+ was generally longer in time such that it conformed to the interstimulus interval (ISI) delay between tone-onset and puff-onset (or, in the case of unpaired trials, potential puff onset). Similarly, the combined characteristics of latency and duration of the eyeblink was such that eyelid closure at the time of puff-onset (or, potential puff-onset) resulted in a greater percentage of responses which successfully avoided puff-onset.

D. A sling-type harness and a plexiglass head holder attached to the head by means of strips of Velero tape, was developed for use with dogs of the basenji strain. Experimentation with this apparatus was undertaken while the present writer was a Visiting Investigator at the Jackson Labs Hamilton Station (Bar Harbor, Maine) from June 1, 1965 to September 1, 1965. Preliminary data suggested that this procedure will permit the recording of eyelid responses from medium sized mammals (such as dogs, sheep, etc.) in a relatively unrestrained situation. This research is not a formal part of the present NASA proposal, but does represent ancillary interests which may develop into a substantial contribution to the general body of knowledge included within the scope of the proposed research program.

CONCERNING STRICTLY SINGULAR OPERATORS

Mr. R. Bruce Mericle

Department of Mathematics and Astronomy

Problem

It is proposed to study further strictly singular operators in normed linear spaces. The notion of a strictly singular operator has been defined as an extension of a compact operator. These have been studied in some detail since 1920 and have found wide application in solutions to differential and integral equations.

Introduction

In (3) Kato introduced the concept of a strictly singular operator, a generalization of the concept of a compact operator. He proved that for X and Y Banach spaces the strictly singular operators form a closed subspace in the space of all bounded linear operators from X to Y and that the product of a strictly singular operator with a bounded operator is strictly singular, so that when $X = Y$ they form a closed two-sided ideal. He further showed that the Riesz-Schauder theorem held for the spectrum of a strictly singular operator on a Banach space.

It is also shown in (3) that if X and Y are Hilbert spaces then all the strictly singular operators from X to Y are compact. In the general case, however, the strictly singular operators not only fail to be compact but strict singularity is not preserved under conjugation. In (2), Goldberg and Thorp give an example of a strictly singular operator, which is not compact, and one where T is strictly singular but T' (the conjugate operator) is not. In (5) R. J. Whitley relates the strict singularity of T to that of T', under certain conditions on the domain and range spaces. In (4) I gave some of the simple characterizations and properties

of compact and strictly singular operators, and also showed how a closed operator can be closely compared to a strictly singular operator. In (4) also, are details of a result announced by Feldman, Gohberg and Markus (1) which is that the compact operators form a maximal ideal in $B(\ell_p)$, $1 \leq p \leq \infty$, the Banach space of bounded linear functions mapping ℓ_p into it. If.

Current Status

What I have proposed is to continue the research initiated in (4), and to see where the strictly singular operators fit in with some other operators that also extend the compact operators. In particular, I am looking at the following classes of operators mapping a Banach space X, into itself:

1) AF(X), the almost-finite operators. An operator T is almost-finite, if it can be uniformly approximated by operators having finite-dimensional range spaces.

2) K(X), the compact operators. An operator T is compact, if T(S) is compact in the norm topology. (Here, S denotes the unit ball of X.)

3) $K_n(X)$, the n-compact operators. An operator T is n-compact, if the operator T^n is compact.

4) PK(X), the potentially compact operators. An operator T is potentially compact, if there is some integer i, so that T^i is compact.

5) WK(X), the weakly compact operators. An operator T is weakly compact, if T(S) is compact in the weak topology.

6) $W_n(X)$, the weak-norm continuous operators. An operator T is weak-norm continuous, if whenever a sequence $\{x_n\}$ converges weakly to x, then $\{Tx_n\}$ converges in norm to Tx.

7) Operators T which are continuous and which also map weakly compact sets into norm compact sets.

8) S(X), the strictly singular operators. An operator T is strictly singular if T is continuous, and if whenever T restricted to a subspace M is an isomorphism, then M is finite dimensional.

We first note that operators 1,2,5,6,7,8 form ideals in B(X), and that we can imbed 3,4 in the minimal closed ideal containing them. It is then noted that $AF(X) \subseteq K(X)$, and that K(X) is contained in the other ideals. (It is an unsolved problem as to whether $K(X) \subseteq AF(X)$, or not.) We will be interested in the following problems:

a) Are all of these ideals necessarily distinct, and under what restrictions on our space X will any two ideals be equal?

b) In particular, under what conditions will any ideal be a maximal ideal? Also, if K(X) is a maximal ideal of B(X), can we say anything about X? This problem is of interest, due to the aforementioned result of Feldman, Gohberg, and Markus, concerning the maximality of K(X) in $B(\ell_p)$. We will conjecture that the maximality of K(X) will impose a severe restriction upon our spaces X, one condition being that X will have to be separable.

c) We would also like to know which ideals carry over into similar ideals of X', (the conjugate space of X), under conjugation, and what restrictions on our space X will guarantee this.

These results will be useful in comparing the strictly singular operators with the other usual operators which extend the compact operators. Then we can possibly extend our results to operators acting in a locally convex topological vector space, a problem which has some interest in the Theory of Distributions.

Relation to Space Science

In relating these results to space science, we will point out that these operators occur in the papers of T. Kato, Gohberg and Krein, S. Kakutani, R. S. Phillips, K. Yosida and others, where they came across these operators in the course of solving a particular integral or differential equation. Frequently, the placing of an integral or differential equation in a Banach space context leads to a simplification of the problem involved. In this respect, since we know that the operators do arise (3), we would like to know more about them, and at the same time, to carry out a general investigation of certain ideals that occur in B(X).

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4) Mericle, R. Bruce: Strictly Singular Operators in Normed Linear Spaces, Master's Thesis, University of Maryland (1964).

5) Whitley, R. J.: Strictly Singular Operators and their Conjugates Trans. Amer. Math. Soc. (1965) 252-261.

January 8, 1966

Dean T. H. Curry
Space Research Chairman
Boardman Hall
Campus

Dear Dr. Curry:

In reviewing my November report, I find that it is quite complete as it stands. Being specific as to the problems outlined on page 3, I note that:

1) The ideals introduced on page 2 are, in general, distinct. A recent paper by Lacey and Whitley (1) reviews part of the problem, and also compares ideals K(X), WK(X), Wn(X), and S(X), as defined in my report. I am in the process now of reading the above paper to see where it would be helpful in my own work.

2) We note that under certain strong conditions on our space X the ideals K(X), WK(X), Wn(X), and S(X) can all be maximal. The problem is to find the weakest condition on the Banach space X, if possible. So far not much work has been done in this area, beyond what appears in the papers (1), (4), and (5) of the previous report.

It goes without saying that any results obtained by me will be incorporated in my final report this coming June.

I hope that this will meet with your approval.

Sincerely yours,

R. Bruce Mericle

1) Lacey, E. and Whitley, R. J.: Conditions under which all the bounded linear maps are compact. Math. Ann. 158(1965), 1-5.

INVESTIGATION OF PARAMETERS FUNDAMENTAL TO OPTIMIZATION OF DRAG TURBINES -

Dr. W. L. Schneider and Prof. J. G. Klavuhn

Proposal

The objective of this investigation is to gain an understanding of the flow mechanism and basic principles of the drag turbine.

So little is known concerning the mechanism of energy transfer and flow in a drag turbine that much work remains to be done. It was decided that an experimental model which would allow the blade depth and channel dimensions to be varied would result in a better understanding of the parameters which optimize the "drag" on the turbine wheel.

Drag turbines are reliable even when operating with high temperature gases carrying foreign particles and can be driven by bleed-off from rocket motors. When size, weight, cost, and reliability are a consideration, as they are in space application, drag turbines can be used for intermittent-duty or for any application except those which require the optimum use of available energy.

Results

Minor modifications have been incorporated into the design of the experimental model mainly to facilitate disassembly of the model for ease of internal configuration change. This in no way changed the basic design described in the preceding report.

Vendors, within a reasonable radius, were investigated for the model fabrication and found to be saturated with work from other sources. The result of this would be poor delivery dates (as well as unreasonable bids). At the same time it became apparent that there would be machine man-hours available at the University which would result in a considerably saving of time and money. It was decided to avail ourselves of this opportunity.

All materials have been ordered and received and machining of the model parts has begun.

Through negotiation with the Worthington Corporation a drag pump has been received as a gift to the Department of Mechanical Engineering. This pump will be used as a loading device for the experimental turbine.

Contact has been made with vendors concerning supplies and equipment necessary for the experimental setup. Orders for these items will be placed shortly.

It is anticipated that during the next few months the model and experimental setup will be completed and that initial de-bugging runs will be made. Collection and analysis of data will continue next summer.

THE EFFECT OF REPEATED ROLLING CONTACT STRESS FIELDS ON THE MICROSTRUCTURE OF HIGH CARBON MEDIUM HARDNESS STEEL - Professor J. R. Lyman

Proposal

The mechanism of initiation of plastic deformation leading to surface fatigue spalling in rolling contact is sought. Specimens whose geometry allow a complete mathematical definition of the contact stress have been built from 52100 steel quenched and tempered to 47 Rockwell C. Pairs are currently being operated in pure rolling under carefully controlled load, speed and lubrication conditions in the M.E. Research Laboratory. The rolling contact test machine has been designed, developed and built at the University of Maine. The problem is to define the characteristic(s) of the stress field responsible for localized microstructural breakdown of the specimens when the stress magnitudes are such that a mechanics defined limit of elastic behavior of the material is not exceeded.

If a basic mechanism of failure initiation in rolling can be related to a stress characteristic, deliberate means may be sought to obviate the damaging stress factor. This will be of value to the designers of contact loaded devices in any field of endeavor.

Progress Report

1. The Do All Company successfully demonstrated the ability of their Model DH-612 precision surface grinder to machine the torus and cylinder so as to expose the principal plane of rolling of these rolling contact specimens. The distance from the reference edge of the specimen to the center of the roll path was estimated using the Tukon microhardness tester microscope and precision microton stage with the rolling contact specimen mounted on it. The grinder finish ground an exposed plane to within 0.0001" of the specification given.

As a result of this work a Model DH-612 Do All Surface Grinder was purchased by the Mechanical Engineering Department with the assistance of this project. It will be in operation in time to do the precision grinding required of specimens tested during the spring and summer of 1966.

2. The Rolling Contact program of the ASME Fall and Winter meeting in Chicago on Nov. 8, 1965 was attended by the principal investigator. As a result of a discussion of one of the papers given there, a paper entitled, "Reversing Normal Strains Produced by Rolling Contact Load," was prepared from the analytical work done on this project. It was submitted to the Editor of ASME around Dec. 1, 1965 and its status with him is as yet unknown.

3. Due to a rearrangement of Mechanical Engineering laboratories, the test machine was disassembled and moved to a new location. The solution of all the problems associated with this move is nearly complete and limited testing should begin shortly.